DRY WEIGHT OF FRESH AND PRESERVED SPIDERS (ARANEIDA: LABIDOGNATHA)[1]

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ABSTRACT: Data on the dry weight for 19 taxa (suborder Labidognatha) of fresh and preserved spiders are presented. The variation in weight at length for individual species is also provided. With the notable exception of the genus *Tetragnatha*, Family Tetragnathidae, the Family Therididae, and most of the genera of the Family Thomisidae, the families examined are similar to one another in their weight-length relationships and are not readily separable on that basis. Dry weight can be approximated using either the weight of fresh specimens or preserved material. The 'typical' spider, based on the material examined, increases in length faster relatively than it increases in weight, and dry weight decreases relative to fresh weight as length increases.

With the exception of the papers by Clausen, 1983, that included data on fresh and dry weight-length relationships for nine species (five families), and Breymeyer, 1967, for three species of the family Lycosidae, there is very little general information available on the dry weight of spiders. This report serves to increase the information available on spider weight and explores the degree of difference between taxa from the weight-length perspective.

MATERIAL AND METHODS

The bulk of preserved material was collected in 1989 and 1990 in the Frances Crane Wildlife Management area, Hatchville, Falmouth Township, Barnstable County (Cape Cod), Massachusetts, in connection with another study (Edwards 1993). Collection details are provided therein. All were preserved in 75% denatured ethanol and all had their alcohol replaced at least once, typically within 48 hours of collection. The total length was measured from the clypeus to the distal end of the abdomen using an ocular micrometer for specimens <12 mm in total length and vernier calipers for those >12 mm. The total length, as described above, was measured to the nearest 0.1 mm, and the specimens damp dried on absorbent paper before weighing. Obviously distorted specimens were not used. In those cases where the pedicel had elongated, the separation of the thorax from the abdomen was measured and the total measurement corrected accordingly.

The fresh material for this study was collected in the months of June through September, 1996, from the same area and habitats as the preserved material with one exception. The collection of *Leucauge regnyi* Simon, Family Tetragnathidae, was made in Puerto Rico in September, 1996. All collections were

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made in the afternoon, the spiders were immobilized in an ethyl acetate collecting jar, identified and measured that day, refrigerated overnight at 3° C, and weighed the following day on a Mettler A200 balance, accurate to 1 mg. Following this, the material was oven-dried at a temperature of 40° C for seven days. To check the efficacy of the drying regime, three samples of 50 or more mixed species samples were dried for an additional seven days, with the greatest additional loss of weight observed of less than 3% in all cases. Specimens of all species used in this study have been deposited in the United States National Museum.

RESULTS AND DISCUSSION

The families, genera, number of individuals weighed, and the range of total lengths are provided in Table 1. A total of 2,315 measurements of fresh, dry fresh, and preserved specimens representing 78 genera and 17 families were made (Table 1). Note in Fig. 1 that the various taxa are identified with the first four letters of the taxon as listed in Table 1.

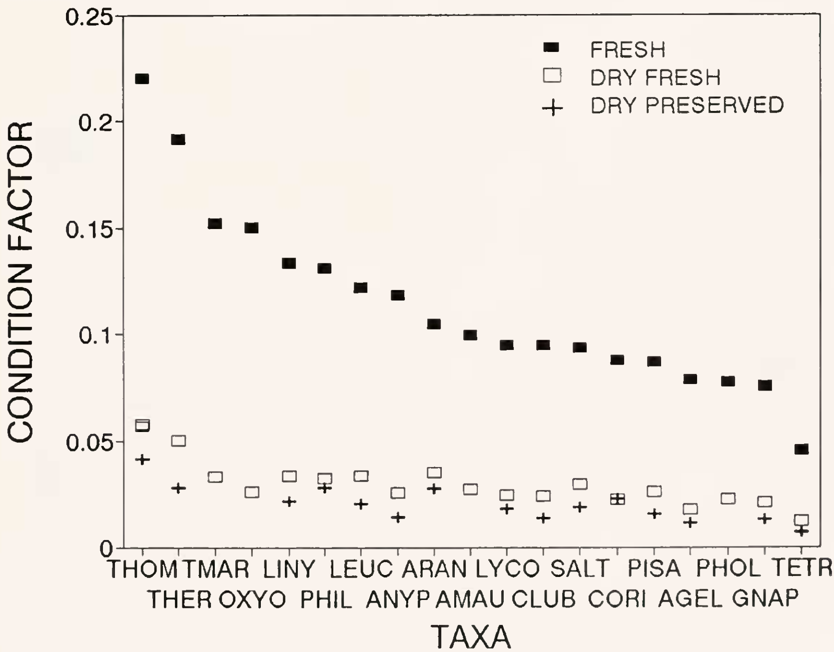

Figure 1. Condition factors for the taxa listed in Table 1, using the equation $k = (aL^b) / L^3$. The taxa are identified using the first four letters of each taxon. There are values for each treatment (fresh, dry fresh, dry preserved) with the exception of AMAU, TMAR, PHOL, and OXYO, for which there was no dry preserved data available.

The log transformed least squares equation, *ln weight = ln a + b (ln length)*, was used to estimate weight (mg) at length (mm). The statistical parameters are provided in Table 2. The coefficient of determination (r^2) ranged from 0.743 (Oxyopidae, dry fresh) to 0.985 (Corinnidae, fresh). Averages, minimum, and maximum values are listed for all parameters. The average values for coefficient *ln a* (intercept) varied considerably and were greatest (-1.976) for fresh and least for dry preserved specimens (-3.580), while the average values for exponent *b* (slope) varied relatively little, from 2.739 for dry preserved to 2.800 for dry fresh specimens (Table 2).

The number of individuals and genera obtained for each family varied considerably (Table 1). It is clear from the statistical parameters presented in Table 2 that there was little difference in the weight-length relationships between taxa. To compare weight at length using different taxa, while taking into consideration the differing length ranges over which the parameters were estimated, we calculated the condition factor for each taxon, $k = (aL^b) / L^3$ (L = mid-point of lengths (mm) in sample, *a* = Exponent *ln a*) and the results shown in Fig. 1. Of the 19 taxa the genus *Tetragnatha* Latreille (Tetragnathidae), the family Theridiidae, and the rotund crab-like members of the family Thomisidae (genera *Xysticus* C. L. Koch, *Ozyptila* Simon, *Misumena* Latreille, *Misumenops* F.O.P.-Cambridge, and *Misumenoides* F.O.P.-Cambridge) stand apart from the rest. The genus *Tmarus* Simon, family Thomisidae, is relatively slender (less crab-like and rotund), differing in this respect from the other genera of the family Thomisidae listed above and is plotted separately (TMAR). Similarly, the less elongate genera *Leucauge* White, and *Pachygnatha* Sundevall, family Tetragnathidae, differ in body form from the elongate members of the genus *Tetragnatha* and are also plotted separately (LEUC). The uniqueness of *Tetragnatha* was noted by Greenstone, et. al. 1985.

Breymeyer (1967) in a study concerning the dry weight of preserved spiders reported that alcohol dissolves and extracts some parts of spider bodies. This appears to be the case in this study as well. It is worth noting that undried specimens preserved in denatured alcohol weigh considerably more than fresh material (Edwards 1996). Clausen (1983, p. 143-144) noted that "the ratio of dry over wetweight increases with decreasing size of specimens", and suggested that "With decreasing size, the exocuticle may make up a relatively greater part of the animal's weight because of the relatively greater surface. And, there may be a minimum thickness of the cuticle, which, in effect, will give the same result." To test Clausen's (op. cit.) suggestion further, the entire data set available was examined by treatment, i.e. fresh, dry fresh and dry preserved. The statistical parameters for each treatment are provided in Table 3. The percent of fresh weight for dry fresh and dry preserved material is shown in Fig. 2. The results are consistent, for the average spider, with the observations of Clausen (op. cit.), with the caveat that more than the cuticle is un-

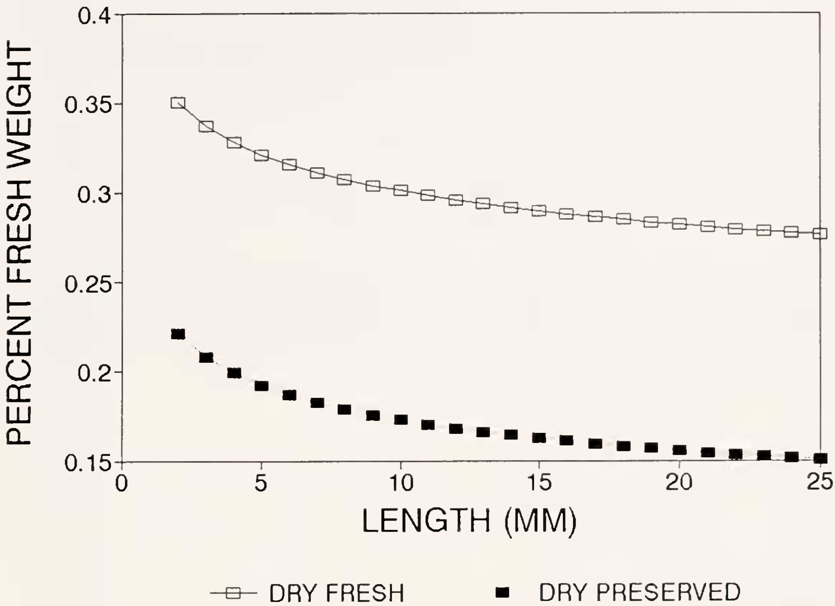

Figure 2. Percent of fresh weight represented by dry fresh weight and dry preserved weight, based on average data for each treatment (Table 3).

doubtedly involved since drying does not reduce the specimens to the cuticle only. Other tissues are involved which may also vary in the degree to which they are present in different taxa.

The variability seen in individual species in the ratio of dry weight to fresh weight was examined for 11 species collected in October and November, 1996. The individual species collections were each made within an hour in restricted localities to reduce environmental variabilities as much as possible. The collections were treated and analyzed as described earlier (see Table 4). On average the ratio of dry to fresh weight was 0.314 ± 0.038, varying from 0.250 to 0.390. The average slope (*b*) of dry on fresh weight was slightly in excess of 1 with two notable exceptions, that of *Pardosa lapidicina* (b = 1.224) and *Phidippus clarus* (b = 1.537). The average intercept (*ln a*) values for these two species were also well in excess of the average value, -2.015 and -3.161 respectively. Both of these collections were of immature individuals that would have matured the following year, although the *Tmarus angulatus* collection, also of immature individuals due to mature the following year, did not have a similar departure from the average values. The average r^2 for the weight-length regressions of these species was 0.892 for fresh and 0.864 for dry fresh.

For studies requiring precision, e.g. those of a single or a set of closely related species, it would be best to use a sclerotized part of the body such as the head capsule, to reduce the problems associated with measurement error (cf. Jocque 1981). Whatever method is used, it is obvious that the weight of individual spiders is highly variable.

In one survey (Edwards 1993) over 12,000 specimens were collected. Many of these were archived against the future. It was encouraging to find out that preserved material also served the purpose of realistically estimating dry weight.

Table 1. Fresh and preserved spiders examined. Number of individuals = n, number of genera = genera, lengths (mm) included in sample = range. Family Tetragnathidae is subdivided into the genus *Tetragnatha* and a second category of rounder body forms, including the genera *Leucauge* and *Pachygnatha*, listed as *Leucauge*. The family *Thomisidae* includes all genera sampled except the genus *Tmarus* which is listed separately.

	Fresh			Fresh, dry			Preserved, dry		
Taxon	n	genera	range	n	genera	range	n	genera	range
Agelenidae	66	5	4.5 - 19.1	29	1	7.4 - 19.1	52	3	3.7 - 16.5
Amaurobiidae	27	1	4.0 - 14.1	26	1	4.0 - 14.1			
Anyphaenidae	28	4	2.7 - 7.6	31	4	3.2 - 7.8	33	3	3.6 - 9.2
Araneidae	90	4	2.7 - 21.2	84		2.7 - 20.5	56	9	2.3 - 14.8
Clubionidae	30	4	2.3 - 8.8	26	3	2.5 - 11.1	19	5	2.0 - 9.0
Corinnidae	20	1	2.2 - 8.6	10	1	3.2 - 11.2	19	1	2.3 - 7.1
Gnaphosidae	82	5	2.8 - 10.1	43	5	3.4 - 9.4	34	5	3.2 - 11.6
Linyphiidae	60	9	1.5 - 5.5	43	5	2.5 - 5.4	56	9	2.0 - 6.5
Lycosidae	92	11	1.5 - 16.8	85	9	4.0 - 16.8	53	11	2.6 - 13.5
Oxyopidae	23	1	4.2 - 7.3	42	1	4.2 - 7.5			
Philodromidae	25	3	2.0 - 9.0	31	3	2.9 - 12.5	39	3	2.0 - 6.6
Pisauridae	16	2	5.5 - 19.3	16	2	4.0 - 11.1	25	1	2.1 - 12.0
Pholcidae	26	1	2.3 - 8.5	26	1	2.3 - 10.8			
Salticidae	83	6	2.3 - 10.1	86	9	3.4 - 10.8	49	6	2.2 - 9.0
Tetragnathidae									
Tetragnatha	58	1	2.5 - 11.0	42	1	3.0 - 10.2	31	1	2.4 - 8.5
Leucauge	49	2	2.5 - 7.6	52	2	2.8 - 7.6	32	2	1.5 - 7.1
Theridiidae	73	7	1.5 - 8.3	55	8	3.0 - 8.2	40	5	1.7 - 6.3
Thomisidae	52	5	1.9 - 8.6	52	3	2.6 - 8.2	41	4	1.6 - 9.1
Tmarus	28	1	4.3 - 6.4	29	1	3.0 - 8.2			
Totals	928	78		808	69		579	68	

Table 2. Statistical parameters for spider weight-length equations (*ln weight ug* = *ln a* + *b* (*ln length mm*), for fresh, dry fresh and dry preserved material. No. of individuals = n, standard error = SE., coefficient of determination = r^2, exponent of *ln a* = Exp *ln a*.

Fresh specimens

Taxon	n	*a* ± SE	*b* ± SE	r^2	Exp *ln a*
Agelenidae	66	-1.657 ± 0.325	2.553 ± 0.113	0.888	0.191
Amaurobiidae	27	-2.303 ± 0.150	2.999 ± 0.077	0.984	0.100
Anyphaenidae	28	-1.697 ± 0.186	2.514 ± 0.116	0.948	0.183
Araneidae	90	-1.726 ± 0.374	2.746 ± 0.066	0.952	0.178
Clubionidae	30	-1.928 ± 0.212	2.636 ± 0.113	0.951	0.145
Corinnidae	20	-2.002 ± 0.111	2.595 ± 0.074	0.985	0.135
Gnaphosidae	82	-2.492 ± 0.237	2.930 ± 0.098	0.918	0.083
Linyphiidae	60	-2.766 ± 0.260	2.647 ± 0.108	0.919	0.171
Lycosidae	92	-1.746 ± 0.277	2.695 ± 0.080	0.926	0.174
Oxyopidae	23	-1.706 ± 0.147	2.571 ± 0.209	0.878	0.182
Pisauridae	16	-2.963 ± 0.207	3.272 ± 0.177	0.961	0.052
Philodromidae	25	-1.707 ± 0.233	2.740 ± 0.135	0.947	0.181
Pholcidae	26	-2.453 ± 0.154	2.905 ± 0.076	0.984	0.086
Salticidae	83	-2.403 ± 0.248	3.027 ± 0.071	0.957	0.090
Tetragnathidae					
Tetragnatha	58	-2.268 ± 0.240	2.431 ± 0.113	0.892	0.103
Leucauge	49	-1.966 ± 0.237	2.853 ± 0.127	0.915	0.140
Theridiidae	73	-1.456 ± 0.222	2.839 ± 0.071	0.958	0.233
Thomisidae	52	-1.447 ± 0.199	2.945 ± 0.086	0.959	0.229
Tmarus	28	-1.860 ± 0.108	2.743 ± 0.177	0.903	0.156
Average		-1.976 ± 0.199	2.771 ± 0.110	0.938	0.148
Minimum		-2.963 ± 0.108	2.431 ± 0.066	0.878	0.052
Maximum		-1.447 ± 0.374	3.272 ± 0.209	0.985	0.233
Dry fresh specimens					
Agelenidae	29	-4.504 ± 0.326	3.184 ± 0.308	0.798	0.011
Amaurobiidae	26	-4.045 ± 0.221	3.198 ± 0.119	0.968	0.018
Anyphaenidae	31	-2.652 ± 0.231	2.406 ± 0.214	0.813	0.070
Araneidae	84	-2.401 ± 0.368	2.615 ± 0.077	0.934	0.091
Clubionidae	26	-3.722 ± 0.265	2.999 ± 0.139	0.951	0.024
Corinnidae	10	-3.896 ± 0.165	3.054 ± 0.175	0.975	0.020
Gnaphosidae	43	-3.584 ± 0.329	2.845 ± 0.198	0.835	0.028
Linyphiidae	43	-2.761 ± 0.260	2.530 ± 0.209	0.830	0.060
Lycosidae	83	-3.253 ± 0.271	2.804 ± 0.093	0.917	0.039
Oxyopidae	42	-3.473 ± 0.269	2.905 ± 0.270	0.743	0.031
Pisauridae	16	-3.107 ± 0.178	2.743 ± 0.182	0.942	0.045
Philodromidae	31	-2.643 ± 0.388	2.617 ± 0.196	0.860	0.071
Pholcidae	26	-3.460 ± 0.462	3.354 ± 0.181	0.953	0.014
Salticidae	86	-3.330 ± 0.289	2.904 ± 0.120	0.875	0.036
Tetragnathidae					
Tetragnatha	42	-2.350 ± 0.285	1.914 ± 0.158	0.785	0.095
Leucauge	52	-3.253 ± 0.272	2.920 ± 0.163	0.866	0.039

Taxon	n	*a* ± SE	*b* ± SE	r^2	Exp *ln a*
Theridiidae	55	-3.436 ± 0.317	3.229 ± 0.177	0.863	0.032
Thomisidae	52	-2.414 ± 0.329	2.741 ± 0.147	0.874	0.089
Tmarus	29	-3.043 ± 0.203	2.790 ± 0.195	0.884	0.048
Average		-3.228 ± 0.278	2.829 ± 0.175	0.871	0.046
Minimum		-4.504 ± 0.165	1.914 ± 0.077	0.743	0.011
Maximum		-2.350 ± 0.388	3.229 ± 0.308	0.975	0.095
Dry preserved specimens					
Agelenidae	52	-5.380 ± 0.375	3.386 ± 0.145	0.916	0.005
Anyphaenidae	33	-3.284 ± 0.267	2.482 ± 0.224	0.798	0.037
Araneidae	56	-3.607 ± 0.484	3.004 ± 0.138	0.898	0.027
Clubionidae	19	-3.356 ± 0.253	2.458 ± 0.146	0.943	0.035
Corinnidae	19	-2.946 ± 0.222	2.463 ± 0.122	0.960	0.053
Gnaphosidae	34	-4.380 ± 0.297	3.011 ± 0.193	0.883	0.053
Linyphiidae	56	-3.308 ± 0.288	2.646 ± 0.120	0.900	0.037
Lycosidae	53	-3.542 ± 0.294	2.772 ± 0.088	0.951	0.029
Pisauridae	25	-3.643 ± 0.307	2.744 ± 0.101	0.970	0.026
Philodromidae	39	-2.801 ± 0.363	2.474 ± 0.213	0.784	0.061
Salticidae	49	-4.139 ± 0.280	3.109 ± 0.124	0.931	0.016
Tetragnathidae					
Tetragnatha	31	-3.590 ± 0.371	2.182 ± 0.181	0.833	0.028
Leucauge	32	-3.589 ± 0.378	2.796 ± 0.183	0.886	0.028
Theridiidae	40	-2.952 ± 0.280	2.553 ± 0.133	0.906	0.052
Thomisidae	41	-3.184 ± 0.210	3.001 ± 0.087	0.968	0.041
Average		-3.580 ± 0.311	2.739 ± 0.147	0.902	0.032
Minimum		-5.380 ± 0.210	2.182 ± 0.087	0.784	0.005
Maximum		-2.801 ± 0.484	3.386 ± 0.224	0.970	0.061

Table 3. Statistical parameters for spider weight-length equations for all available material by treatment. Equation and table headings as in Table 2.

Treatment	n	*ln a* ± SE	*b* ± SE	r^2	Exp. *ln a*
Fresh	928	-1.874 ± 0.447	2.733 ± 0.031	0.891	0.153
Dry fresh	808	-2.857 ± 0.436	2.637 ± 0.039	0.847	0.057
Dry preserved	579	-3.279 ± 0.537	2.581 ± 0.046	0.829	0.038

Table 4. Variability in ratio of dry weight/fresh weight, based on collections of eleven species made at one time in restricted localities. Number of specimens = n, lengths (mm) in sample = Range (mm), dry weight/fresh weight = d/f, coefficent = *ln a*, exponent = *b*, coefficient of determination = r^2, Remarks as follows: Immature only = 1, late preadult and adult ♀♀ = 2, late immature and adult ♂♂ and ♀♀ = 3, and all stages = 4.

Mean									
Species		n	Range (mm)	d/f ± SE	Range d/f	*ln a*	*b*	r^2	Remarks
Agelenidae.	*Agelenopsis pennsylvanicus* (C.L.K.)	29	7.4-19.1	0.311 ± 0.029	0.251 - 0.370	-1.313	1.031	0.984	3
Amaurobiidae.	*Callobius bennetti* (Blackwall).	18	4.0-14.1	0.265 ± 0.038	0.194 - 0.327	-1.608	1.093	0.993	4
Araneidae.	*Argiope trifasciatus* (Forskål)	18	12.1-20.5	0.334 ± 0.030	0.281 - 0.405	-1.608	0.889	0.968	2
Lycosidae.	*Pardosa lapidicina* Emerton	23	4.9- 7.5	0.270 ± 0.033	0.223 - 0.323	-2.015	1.224	0.921	1
Oxyopidae.	*Oxyopes salticus* Hentz	16	4.2- 7.3	0.319 ± 0.023	0.297 - 0.368	-1.299	1.058	0.978	3
Pholcidae.	*Pholcus phalangioides* (Fuesslin)	26	2.3- 8.5	0.313 ± 0.044	0.258 - 0.400	-1.109	0.973	0.987	4
Salticidae.	*Phidippus clarus* Keyserling	20	6.1- 8.4	0.295 ± 0.048	0.222 - 0.391	-3.161	1.537	0.985	1
Tetragnathidae.	*Leucauge regnyi* Simon	39	2.8- 7.6	0.292 ± 0.048	0.208 - 0.379	-1.399	1.058	0.953	4
Tetragnathidae.	*Tetragnatha versicolor* (Walck.)	26	3.4- 9.5	0.389 ± 0.049	0.303 - 0.514	-0.946	1.004	0.937	4
Theridiidae.	*Achaearanea tepidariorum* (C.L.K.)	23	2.9- 8.3	0.299 ± 0.053	0.194 - 0.409	-1.309	1.030	0.972	4
Thomisidae.	*Tmarus angulatus* (Walck.)	22	4.2- 5.9	0.367 ± 0.022	0.316 - 0.401	-1.137	1.053	0.972	1
Means				0.314 ± 0.038	0.250 - 0.390	-1.536	1.058	0.966	

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LITERATURE CITED

Breymeyer, A. 1967. Correlations between dry weight of spiders and their length and fresh weight. Bull. acad. Pol. Sci. CI-II, XV(5):263-265.

Clausen, I.H.S. 1983.Weight-length relations of eight species of spiders (Araneae) from Denmark. Ent. Meddr 50:139-144. Copenhagen, Denmark 1983.

Edgar, W. D. 1971. Seasonal weight changes, age structure, natality and mortality in the wolf spider *Pardosa lugubris* in Central Scotland. Oikos 22:84-92.

Edwards, R. L. 1993. Can the species richness of spiders be determined? Psyche. 100:(3-4)185-208.

Edwards, R. L. 1996. Estimating live spider weight using preserved specimens. J. Arachnol. 24:161-166.

Greenstone, M. H., C. E. Morgan and A. Hultsch. 1985. Ballooning methodology: equations for estimating masses of sticky-trapped spiders. J. Arachnol. 13:225-230.

Jocque, R. 1981. Size and weight variations in spiders and their ecological significance. Biol. Jb. Dodonaea. 155-165.